2019-06-13

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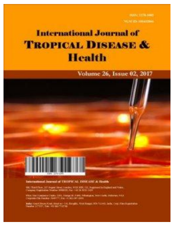
International Journal of TROPICAL DISEASE & Health

https://doi.org/10.9734/ijtdh/2019/v36i330145



International Journal of TROPICAL DISEASE & Health

36(3): 1-11, 2019; Article no.IJTDH.49299
ISSN: 2278–1005, NLM ID: 101632866

Ecological Factors and the Prevalence of Trypanosome Infections and Its Economic Implications for Livestock Industry in Simanjiro, Tanzania: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author KN designed the review, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SM and CDR managed the analyses and the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJTDH/2019/v36i330145
Editor(s):
(1) Dr. Arthur V. M. Kwena, Professor, Department of Medical Biochemistry, Moi University, Kenya.
Reviewers:
(1) Muhammad Haruna, Federal College of Wildlife Management, Nigeria.
(2) Jose Santos Angeles Chimal, University Autonomous of Morelos State, México.
Complete Peer review History: http://www.sdiarticle3.com/review-history/49299

Review Article

Received 23 March 2019
Accepted 03 June 2019
Published 13 June 2019

ABSTRACT

Aims: Trypanosomosis is among one of the tropical neglected diseases which have impacted on human, livestock and wildlife. Different factors have been discussed by various researchers but ecological factors being considered in nutshell. This paper aimed at reviewing details on how the ecological factors influence the prevalence of trypanosome.
Study Design: Literature review where various literatures have been reviewed and the information synthesized. This paper has placed focus on: habitat type, wildlife management type, wildlife abundance and diversity, fire incidence and human activities.
Place and Duration of Study: This literature review work focused in Tanzania mainland and specifically on Simanjiro district for economic implication of trypanosomiasis for the period of 2011-2013 years.

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Methodology: Literature Searching was done using key words in the following search engines Research gate, (https://www.researchgate.net), Google scholar, (https://scholar.google.com/), and PubMed. Manual search in printed documents were done in reports from government, poster, proceedings and publications which were not available in the internet.

Results: Variation of habitat types was observed to have impacts on spatial and temporal distribution of various tsetse flies and wildlife species which are vector and reservoirs of the diseases respectively. Incidence of fire affected the distribution of tsetse flies, wildlife and prevalence of trypanosome. For the interval of three years (2011-2013) a loss of more than 1million USD associated with trypanosomiasis is estimated in Simanjiro district. More money is used by pastoralists in treatment of animals than in spraying pesticides.

Conclusion: It is recommended that, more work to be done on the impact of ecological factors on trypanosomiasis. Also more effort is required in controlling the disease through collaboration of different stakeholders such as livestock officers, ecologists, veterinarians and other relevant agencies.

Keywords: Ecological factors; prevalence; trypanosomiasis; tsetse flies.

1. INTRODUCTION

Trypanosomiasis is among of neglected, zoonotic and vector borne diseases which affect livestock , wildlife and human in Africa [1,2]. Trypanosomes species in Africa are the parasites and causative agent for the disease. The well-known trypanosomes species includes; *Trypanosome congolense, T. brucei* and *T. vivax* which infect animals like cattle and wildlife. The common species that causes Human African Trypanosomiasis (HAT) in man (sleeping sickness) in East Africa is *T. brucei rhodesiense* while *T. brucei gambiense* is known in West and central Africa. Tsetse flies of genus *Glossina* is the main vector for the parasite *Trypanosome*. The species of economic importance include *G. pallidipes, G. brevipalpis, G. morsitans and G. swynnertoni* because they transmit trypanosomosis in both cattle and humans through biting mechanism [1,3,4].

The trypanosomiasis disease is of social and economic importance to people particularly the pastoral communities/livestock keepers. In countries like Angola, Democratic Republic of the Congo (DRC), and South Sudan, sleeping sickness was observed to be greater killer than HIV and AIDS. Tanzania shares borders with Uganda, Kenya and the Democratic Republic of the Congo (DRC) in this country more than 80% of the cases registered in the WHO have been reported [5].

The parasites can be diagnosed in by several ways, in cattle for instance, Giemsa stained thick and thin blood smears, nested ITS-PCR and SRA LAMP technique are popular although some are expensive [3,4,26]. In cattle, trypanosomiasis can result into lowered herd fertility, high incidences of abortions, low birth weights, reduced growth rates, reduced milk yield and poor beef quality thus leading to poor livestock off takes as well as low revenues [6]. Although, African cattle breed are genetically resistance to trypanosomosis (trypanotolerance), yet the morbidity and mortality is high. For the sick cattle, mortality can reach 100% [7]. The seasonal cattle movement, drought, change in pasture and water sources and ecological factors accelerated the mortality and morbidity [28,66]. However, most of wildlife species are reservoir to the trypanosomes parasites [17,18]. This shows that, ecological factors are essential on influencing the prevalence of trypanosomes infection.

This review paper aimed at assessing how the ecological factors play role in prevalence of trypanosome infection while highlighting the economic loss caused by trypanosomiasis, through literature review. Secondary data from Simanjiro District of Tanzania were used as a case on determining the economic loss caused by trypanosomosis. The ecological factors considered here are: different types of wildlife management (National park, Game reserve, and Wildlife management area), Habitat and human disturbance.

2. MATERIALS AND METHODS

2.1 Literature Search for Ecological Factors

Extensive study was conducted in literatures of both printed and those in internet as suggested by Khan et al. [8], Mcdonagh et al. [9] and language was not used as criteria for restriction.

A search strategy involved using key word in internet and reading different printed documents. The key words as shown in Table 1 were used in the search engine like Research gate, (https://www.researchgate.net), Google scholar, (https://scholar.google.com/). PubMed and manual search in printed documents were done in reports from government, posters, proceedings and publications which were not available in the internet. The information required in this study was trypanosome prevalence in Tanzania in cattle, pigs, flies, wildlife and humans, ecological factors (here wildlife, wildlife management types, habitat and human activities).

The review on influence of ecological factors involved comparing the variation in prevalence of trypanosome infection in various ecological zones in Tanzania. The different ecological zones included the varying distance from protected area such as National Park (NP), Game Reserve (GR) and Wildlife Management Area (WMA). Also the influence of other ecological factors and human activities were taken into account. Tanzania has different wildlife management types with different influence in wildlife population, tsetse flies abundance thus trypanosome prevalence in cattle. These include; National Parks like Serengeti National Park, Ruaha National Park, Saadani National Park and Tarangire National Park which have no consumptive utilization of wildlife. Game reserves like Selous Game Reserve, and Uwanda Game Reserve; allow consumptive utilization of wildlife resources (tourist hunting).

2.2 Economic Implication

The secondary data were obtained from Simanjiro district office. The data involved those collected from 2011 to 2013. The information reported were those showing the number of animals which were diseased, treated and recovered at that particular time interval. Simanjiro district was selected because, is among the areas which are well known to be impacted with trypanosomosis. To get the monetary value of the loss caused by the death of cattle [10], Pugu cattle market price of 350USD (Tsh781,000/=) per cattle was considered in a year 2018 [11]. The cost for treating one cattle per year estimated to be 5.5 USD while cost for spraying tsetse flies with insecticide and other management practices (including diagnostic, treatment, health care) was estimated to be 3.5USD per cattle per year based on a study in Uganda that estimated the cost effective of trypanosome management [12]. However quality lives for human and expensive diagnosis techniques were not considered because they are not frequently used at village level.

3. RESULTS AND DISCUSSION

3.1 The Prevalence of Trypanosome Infection and Ecological Zones

In this study it was observed that 18.33% of the documents reviewed showed that, high prevalence of trypanosome species were observed in sample taken near protected area than those taken far from protected area (Table 2). About 6.7% of the records revealed that, human activities have negative effect to the habitat of vector and hosts of *Trypanosomes* which have implication in prevalence of infection.

The overall average prevalence was 23.94%. The prevalence of *Trypanosome* species among sampled sites varied. The highest prevalence was reported in area near Ngorongoro conservation area [4] while the least was observed in area near Serengeti national park [13] (Table 3).

3.1.1 How ecological factors affects the prevalence of *Trypanosome* in cattle

In order to understand the influence of ecological factor on the prevalence of *Trypanosome*, we need to know what is ecosystem, the components of ecosystem and which of the components are the key factors on the epidemiology of trypanosomosis [14]. Living organisms and their interaction with the environments forms the ecosystem and the study of it is called ecology. The components of the ecosystem are biotic factors which consist of living organisms like plants, animals and microbe (producers, consumers and decomposers) and abiotic factors like air, soil, water and climate [15]. The ecological factors for the trypanosomes are those components or parts of the components which influence the survival, distribution, and prevalence. These factors do not affect the parasite directly but indirectly through the hosts and vectors responsible to carrying the parasite. The hosts being wildlife, livestock and human being while the main vector being Tsetse flies. The ecological factors of wildlife abundance and diversity, habitat type, wildlife management (Biodiversity conservation), fire use and human activities have influence on the prevalence of *Trypanosome* and herein discussed.

Table 1. Identification, screening and eligibility of the documents included in the study

Identification	Screening	Eligibility	Key word used for searching
Record from Google scholar (n= 250) Med pub (n=150) Research Gate (n=50) Manual search (n=20)	Documents screened (n=470) 219 Included- Full texts 251 Excluded- had only titles and/or abstract	60 full text included, 192 excluded Reason; No ecological data, wildlife management status, habitat status, human activities	Prevalence of trypanosome in Tanzania, Protected areas, Trypanosome and human activities, ecological, wildlife, Influence of ecological factor on prevalence of trypanosome

Table 2. The impacts of various ecological zone and human activities to prevalence of trypanosomes

C/N	Ecological zone	Intervention	Implication in prevalence	Reasons	References
1	National Park (NK)/Game reserve (GR)	Near (NP, GR)	Higher than far	High Interaction of wildlife-livestock Intact habitat for vector (Tsetse flies)	[56,57,58,28]
		Far (NP, GR)	Low than near	Low wildlife-livestock Interaction High habitat disturbance for host and vector (Tsetse flies)	[3,2,59,54]
		Inside(NP,GR)	High	High diversity and abundance of wildlife host species High diversity of parasite species	[18]
3	Wildlife Management area (WMA)	If compared to NP,GR	Low	-human activities allowed -habitat disturbed -low conservation level	[54,60,2]
4	Human disturbed area	Highly, low or none disturbed	Low in disturbed area	-Habitat loss for tsetse flies and wildlife host	[2,23,61,62,37,38]

Table 3. Prevalence in different ecosystem (NP, GR and WMA) with the nearby conservation area were recorded

c/n	Prevalence	Ecosystem/nearby protected area	Method used	Host sampled	Ref
1	27.8 % (95 % CI 22.3-32.5 %)	Near Tarangire, NP	Serum resistance associated (SRA) LAMP technique	Cattle	[4]
2	47 %, 91.7 %, 60.8 %	Near Ngorongoro Conservation area	SRA LAMP technique	Cattle, sheep, goat respectively	[3]
3	0.010% and 0.0085%	Serengeti National Park (N.P)	Polymerized Chain Reaction (PCR)	Tsetse flies (*G. swynnertoni G. pallidipes,* respectively)	[13]
4	16.7%	Manyara N.P, Tarangire N.P,	PCR	Pig	[26]
5	5% (95%CI=2.6-8.6).	Tarangire N.P	Giemsa stained thick and thin blood smears	Cattle	[54]
6	7% (95%CI=5.2-8.9).	-	Dissection method	Tsetse flies	[63]
7	6.6% (13/197).	Selous Game Reserve (GR)	PCR	Tsetse flies	[62]
8	6%	Saadani NP and Serengeti NP	PCR	Tsetse flies	[64]
7	51.47%.	Mikumi NP	nested-PCR	Cattle	[65]

Table 4. The cattle diseased by Trypanosomiasis, treated, recovered, died and the economic loss associated with Death, treatment and spray. Note; Price of cattle is 350USD [11], Treatment cost per cattle per year 5.5 USD and cost for spray per cattle per year is 3.5 USD [12]. Although it was not possible to get the total number of cattle in year 2011 and 2013, we succeeded to get the total number of cattle in the year 2012 was 347,489

Year	Diseased	Treated	Recovered	Died	Loss by Death (USD)	Loss by Treatment (USD)	Loss by spray and control (USD)	Total cost (USD)
2011	7414	7398	6843	762	26 6,700	40,689	25,949	333,338
2012	9431	8582	8612	916	320,600	47,201	33,009	400,810
2013	7399	7287	6539	871	304,850	40, 079	25,897	370,826
Total	24244	23267	21994	2549	892,150	127969	84,855	1,104,974

3.1.2 Wildlife abundance and diversity

Higher prevalence was observed to the samples collected near protected area than far ones. This can be explained by the presence of wildlife species which act as reservoirs to the parasite. Wildlife is undomesticated fauna and flora [16], for the context of this paper wildlife is considered to be all wild animals. The abundance of wildlife refers to the number of wildlife (Species evenness) while diversity refers to the variety of wildlife species (combination of species evenness and richness). The diversity and abundance of wildlife species have great influence in the availability of the *Trypanosome* parasite. Different wildlife species are favored and affected differently by tsetse flies (as Vector). Studies have shown that some wildlife species are more affected than others. A study done in Luangwa valley Zambia, showed variation among prevalence of *Trypanosome congolense, T. brucei* and *T. vivax* in wildlife [17,18]. Animals like cape buffalo (*Syncerus caffer*), warthogs(*Phacochoerus africanus*), The Cape bushbuck or imbabala (*Tragelaphus sylvaticus*) and waterbuck (*Kobus ellipsiprymnus*) were detected to have the trypanosome parasite while species like elephant (*Loxodonta africana*), spotted hyena (*Crocuta crocuta*), giraffe(*Giraffa* sp) and duikers(*Cephalophus* sp) observed to have less impact on harboring the trypanosome parasite [17-19]. Possibly meal preference for tsetse flies and quantity of sampled animals can explain this. Regardless of the detected parasites in wildlife above, several studies have showed that, wildlife are resistant to the parasites and they do not show clinical signs thus acting as reservoirs [20].

The presence of wildlife makes the trypanosome to circulate in the ecosystem. Regardless of the control strategies carried out by livestock keepers and other persons [21], yet the presence of the wildlife host the Trypanosomes species which will later be spread to other hosts like human being and livestock. Most of wildlife species are found in protected area where tsetse flies control strategies are rarely implemented. For instance, in most pastoral communities found outside protected area, the controls are done but not inside the protected areas. A study done in North Vietnam revealed that, there were higher cases of *Trypanosome avansi* in buffalos than in cattle. Ecological factors comprising wildlife species were pointed out to be among the influencing factors [22], although, control practices, treatments to cattle can be among the reason. Also resistance of wildlife (example, buffaloes) to trypanosomes infection could lead into low mortality rate in infected buffaloes than infected cattle [20].

3.1.3 Habitat type

In a simple term, habitat can be explained as locality which supports life to living organisms by providing the basic requirements for example food, shelter, breeding ground and other basic needs [23]. There are different types of habitats, World Wildlife Fund (WWF) describes that the major types of habitats are terrestrial, freshwater and marine ecoregions while terrestrial is the most diverse [24]. However in the case of this paper, terrestrial habitat are the one that influence epidemiology of the trypanosomosis. Habitats like grassland, woodland, bush land and forests, alone cannot have direct influence on the trypanosomes parasites without the hosts for the parasite; in this case tsetse flies (Vectors) and wildlife the reservoirs. [25] noted that domestic dogs, cats and pigs [26] are reservoirs to *Trypanosoma cruzi* while tsetse fly (*Glossina* spp.) are intermediate host and vector of African trypanosomes [27]. Furthermore, a study done in Maasai Steppe Tanzania, showed that, apart from sex, herd size, previous infection and ages having influence in the infection rate of trypanosome in cattle [28], yet grazing pattern to different habitats types such as woodland and proximity to Tarangire National park has impact on the infection rate of trypanosome in cattle.

In case of tsetse flies, [29–31] have reported that the surface affected by Fusca group are Swamp forest (100%) followed by Closed evergreen lowland forest (95.5%) while being least in Croplands (0.5%) and Sparse grassland (0.7%). Generally different group of tsetse flies are favored by different habitat for instance *fusca* group are found in forest, Nemorhina (*G. palpalis*) are found in savannah while Glossina *(G. morsitans* group) are from riverine habitats. Habitats influence the species of the vector (Tsetse flies), intrinsic and extrinsic behavior of vectors [32] .

Wildlife species need habitat for survival. Habitat type plays great influence on the distribution, abundance and diversity of wildlife species [33]. For instance species like African buffalo (*Syncerus caffer)* is known to be the host for *Trypanosoma vivax, Trypanosoma congolense, Trypanosoma brucei* [32]. 'Miombo' woodlands, woodlands, forests being preferred habitats for

African buffalo while tropical and subtropical forests, muddy and swampy areas for water buffalo [34]. These mentioned habitats also host tsetse flies, vector of trypanosomes. Thus the interaction of habitats, host animals and the vector makes sustainable circulation of the parasite in the ecosystem possible till they meet uninfected animal [35].

3.1.4 Wildlife management (Biodiversity conservation)

The variability of life form at level of species diversity, genetic diversity and ecosystem diversity is termed as biodiversity [36]. Biodiversity have many benefits to man including aesthetical value, social value, spiritual value, cultural, ecological value and economical value [36]. Regardless of the importance of biodiversity yet, threats like over-exploitation, extinction of species, pollution, poaching, invasive species, climate change, habitat conversion and urbanization need to be addressed [36,37]. Biodiversity conservation and management is among the strategies to address the threats to biodiversity. Variation in conservation methods has significant influence on the abundance and diversity of insects such as tsetse flies the vector of trypanosome parasite. For instance, a study done in MUNGATA Wildlife management area near Selous Game Reserve, Tanzania where human beings are living and carry some socio-economic activities showed a decline in abundance and diversity insect compared to areas inside the Selous Game Reserve which is intact [37]. The decline in abundance and diversity of insects in an area in relation to management system can be good indicators to reflect on tsetse flies and the trypanosome parasite they transmit.

3.1.5 Fire use

Fire ecology is not a new phenomenon in the conservation biology. It involves the understanding in which fire occurs in the ecosystem and how it relates with biotic and abiotic factors [39,40]. For our case it relates with wildlife (Hosts/Reservoirs), vegetation (Habitats), Tsetse flies (Vectors) and trypanosomes (Parasites). Fire has both positive and negative effects in ecosystems in general and trypanosomes in particular. The benefits of fire include, reduction of competition for surviving species by influencing the survival of fire adapted species while discouraging the non-fire adapted species [41,42], increases forbs dominance [43] and new animal colonization [44,45]. The promoted plant species or the suppressed can have advantages to the wildlife, vector (tsetse flies) and trypanosome by providing favorable or unfavorable habitats respectively.

Fire increases soil fertility through converting nutrients available to plants into simple water-soluble salts [46]. Fire helps to control soil pH [47] controls pests and parasites [48,49], reduces over accumulated hazardous fuels [49], improves vegetative communities, increase palatability of pasture to herbivores, improve accessibility and habitat for wildlife and livestock which act as host to trypanosomosis [50,51]. Fire affects animals and vegetation directly by killing, decreasing litter decomposition caused by a decrease in microorganisms, promotes pathogen infestation, parasitic organisms (like Trypanosomes) and insects to animals and plants through wound and scars caused by fire [51]. In this case fire plays great role in the spatial distribution of tsetse flies, wildlife and livestock which have implication on the prevalence of trypanosome in a particular area.

3.1.6 Human activities

Human actions osn their environment have impacts on the ecological components including the tsetse flies and the trypanosomes. Human activities includes the following; agriculture, hunting, livestock keeping, fire use, wild honey collection, tsetse flies control strategies and livestock management regimes [52]. For instance, [52] noted that, transhumance practiced by pastoralists in Nigeria during dry season for searching pasture and water, increases the prevalence of trypanosome in cattle due to stress as results of drought, food and water shortage, increased susceptibility of cattle to trypanosomes, higher density of tsetse flies favored by low humidity/high temperature.

In addition, expansion of farm land made many pastoralists to transform from sedentary to semi-sedentary model of cattle keeping which increase the vulnerability of cattle for tsetse flies and trypanosomosis [52,53]. Other human activities are known to have negative correlation with the prevalence of trypanosome. For instance, studies have shown that, hunting of wildlife, fire use and bush clearing for agriculture decreases the availability of tsetse flies and thus the prevalence of trypanosome [33] to animals (Livestock and human being) [4,54]. The negative correlation is attributed by the decrease in habitat quality, quantity and diversity. Also the reduced blood meal from the poached wildlife can explain the negative correlation. For instance; a study done in Burkina Faso, revealed that, Riverine tsetse flies are well adapted to swampy forest. The clearing of such habitat (deforestation) through charcoal extraction, cultivation, fire use for livestock pasture improvement will alleviate them. Also, hunting (Poaching), human/wildlife conflict, activities reduces the availability wildlife species which provide blood meals to tsetse flies and act as reservoirs for trypanosomes [33].

3.2 Trypanosomosis Economic Implications in Simanjiro District

For three years (2011 to 2013) the overall estimate of cost due to trypanosomosis treatment, death of animals and insecticide spray was more than 1Million USD in Simanjiro District. The highest loss was observed in 2012 and being low in 2011. More money is spent in treatment than in spraying insecticide (Table 4).

It is observed from this paper that, trypanosomosis shows significant impacts in terms of economic loss to pastoralists' communities, in this study, only treatment; death and sprays for animals were considered as potentials cause of economic loss to pastoralists. However, if other factors were to be considered the cost could go up beyond 1 Million USD estimated in Simanjiro District. Other potentials factors which can cause more loss due to trypanosomosis can be research, transportation, veterinary services, grazing strategies to control trypanosomosis and health risk (zoonotic) of transmitting parasite from animal to human. The results is with agreement with report from Northern Nigeria which showed that, cost for treatment against trypanosomosis for nine years (1952-1960) went up to £200,000 for approximately total of 4,000,000 doses while the cost to the government went up to £1,000,000 in terms of staff, transport and maintenance of almost 350 treatment camps [55].

4. CONCLUSION

Ecological factors play significant roles in the prevalence of trypanosome. Different stakeholders are required to be involved in the control strategies of the diseases. The stakeholders who can be involved in control strategies included the following: livestock keepers, conservationists, policy makers, nongovernmental organization which are involved in the control efforts of the trypanosomiasis. Unless the control strategies for trypanosomosis and the associated tsetse flies are emphasized, the economic loss caused by trypanosomosis is anticipated to continue among the livestock keepers in ecological zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

ACKNOWLEDGMENTS

We are thankful to the University of Dodoma (UDOM) and Tanzania Wildlife Research Institute (TAWIRI) particularly the Kingupira Wildlife Research Center for support in terms of provision of facilities and space that enabled writing of this paper.

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